ConCEPT – Consolidated Community Emissions Processing Tool
An Open-Source Tool for the Emissions Modeling Community

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ABSTRACT

The new CONCEPT (CONsolidated Community Emissions Processing Tool) Emissions Processor is now available for use by the emissions modeling community. Developed as joint project between Alpine Geophysics, LLC and ENVIRON Corporation, with Midwest RPO and joint RPO funding, the CONCEPT model combines the best attributes of current emissions modeling systems into an open source model highlighting the following features:

- Open Source. Written primarily in PostgreSQL, the software required for running CONCEPT is in the public domain. The model itself is GNU Public License (GPL) compliant and users are encouraged to make additions and enhancements to the modeling system.

- Transparent. The database structure of the model makes the system easy to understand, and the modeling codes themselves are extremely well documented to encourage user participation in the customizing the system for specific modeling requirements.

- Quality Control. The CONCEPT model structure and implementation allows for multiple levels of QA analysis during every step of the emissions calculation process. Using the database structures, an emissions modeler can easily trace a process or facility and review the calculation procedures and assumptions for any emissions value.

The CONCEPT model includes modules for the major emissions source categories: area source, point source, on-road motor vehicles, non-road motor vehicles and biogenic emissions, as well as a number of supporting modules, including spatial allocation factor development, speciation profile development, growth and control for point and area sources, and CEM point source emissions handling. The emissions modeling community has already begun development of additional CONCEPT support modules including CEM preprocessing software, graphical QA tools, and an interface to the traffic demand models for on-road motor vehicle emissions estimation.

This paper describes the features and improvements incorporated into each section of the CONCEPT system. We will identify the advantages of the CONCEPT modeling approach, and discuss areas of potential improvement. Finally, we discuss the plans and paths for additional CONCEPT development.

INTRODUCTION

The production of high quality emissions modeling inventories for input into a wide variety of atmospheric photochemical and aerosol models continues to be an exacting, labor intensive process. The current emissions models available all have demonstrated advantages and drawbacks. The Sparse Matrix Operator Kernel Emissions (SMOKE)[1] modeling system does not require the purchase of expensive third party software, executes quickly, and provides a wide variety of execution options. However, the sparse matrix processing algorithm has proved difficult for use with ad-hoc reporting and quality assurance (QA) processes, and is not 'transparent". Indeed, when attempting to QA the emissions result for a particular source or category, it is very difficult to trace the calculations performed on that source. Although the SMOKE software is provided at no cost, copyright issues prevent users from making and distributing their own customized additions or corrections. The Emissions Modeling System (EMS)[2] is written in SAS[3], which provides easy access and QA of intermediate data and processing steps, but the SAS system is costly, requires annual maintenance fees, and locks the system into a single software vendor. The SAS system is also I/O intensive, and can be prohibitively slow for some types for processes (notably on-road motor vehicle processing). The Emissions Processing System (EPS) is FORTRAN based, and publicly available, but does not have the flexibility offered by SMOKE and EMS.

Recognizing these limitations, researchers at Lake Michigan Air Directors Consortium and the University of California at Riverside prepared a report describing the functionality necessary to build the next generation emissions modeling system[4]. As a result of their efforts, Alpine Geophysics, LLC and ENVIRON Corporation, with Midwest RPO and joint RPO funding, have designed and implemented the initial version of the CONsolidated Community Emissions Processing Tool (CONCEPT)[5].

TECHNICAL APPROACH

The goal of the CONCEPT community model development effort is to produce a basic emissions modeling system, and to provide a robust foundation for additional model development. The design team has explicitly addressed these features in the design of the model system:

- Open Source: Written primarily in PostgreSQL[6], the software required for running CONCEPT is in the public domain. The model itself is GNU Public License (GPL) compliant and users are encouraged to make additions and enhancements to the modeling system. Of note, MOBILE6[7] and NONROAD[8] are integral components of CONCEPT. Because MOBILE6 and NONROAD are coded in FORTRAN, a suitable compiler is required, and one may be inclined to purchase such; however, we have no reason to believe that GNU FORTRAN[9], which is GPL compliant, will fail in this task, though we have not tested it.

- Transparent: The database structure of the model makes the system easy to understand, and the modeling codes themselves are extremely well documented to encourage user participation in customizing the system for specific modeling requirements.

- Quality Control: The CONCEPT model structure and implementation allows for multiple levels of QA analysis during every step of the emissions calculation process. Using the database structures, an emissions modeler can easily trace a process or facility and review the calculation procedures and assumptions for any emissions value. CONCEPT can be run with a variety of debug and QA options that control the number of intermediate tables and reports that are available for the user to review.

The core development software for the CONCEPT system is the PostgreSQL database engine, running on the Red Hat Linux operating system. In addition, the following plug-in packages, all in the public domain, are also required: perl[10] (to facilitate data input-output from the SQL data base and data reporting); and PostGIS[11], GEOS[12] and PROJ4[13] (to facilitate spatial processing).

The emissions model has been developed in a modular fashion, with five primary source category models, and a group of secondary support models that will serve each of the primary models. The major emission source categories are treated as the primary models:

- Area Source;
- Point Source;
- On-road Motor Vehicle, with MOBILE6;
- Non-road Motor Vehicle with the NONROAD model; and
- Biogenics.

The overall framework architecture and database design were created during the development of the point and area models. During the development process, structural requirements were refined for the unique attributes of the motor vehicle, biogenic, and NONROAD models. The supporting system models accommodate all of the primary models, as required. The required supporting models are identified as:

- Speciation profile development;
- Spatial surrogate development; and
- Growth & Control with Cost Analysis.

Area Source Model

The primary goal of the area source model is to take the area source emissions totals provided in the NEI[14], and allocate them to hourly, gridded emission estimates ready for input into the selected air quality model. The CONCEPT area source model is designed to input the ASCII NEIv3 emissions inventory data, without any pre-processing requirements. CONCEPT is currently capable of producing emissions files for input into CAMx[15] and CMAQ[16]. Described below are the key issues of the CONCEPT area source model.

Temporal Allocation

The NEI data format allows area source emissions data to be input in a wide variety of temporal definitions. The temporal processing in CONCEPT selects the temporal record most appropriate for the modeling episode, and will use those emissions values in preference to others. This allows the user to take maximum advantage of the NEI temporal input options. The area source temporal allocation method is designed to handle input data in different time zones. Emissions may be entered in any time zone, and model output results are automatically translated into the designated output time zone. This permits the model to be applied to any country/region in the world.

Speciation

CONCEPT provides a mechanism for pollutant-to-pollutant conversion and application of lumped speciation profiles by pollutant, chemical mechanism, and SCC. Speciation profiles may also be differentiated at the state and county levels. The speciation processor in CONCEPT transforms the input pollutants to the appropriate speciated pollutants using the chemical mechanism specified in the model input, and also converts a variety of input units of measure to a standardized set of output emissions

units (e.g. gm-moles/hr for the CB-IV chemical mechanism). The speciation profile development tools provided with CONCEPT can be used to generate the appropriate profiles for the speciation processor.

Spatial Allocation

Spatial surrogates allocated per the emissions modeling grid are required to allocate county level area source emissions to particular model grid cells. CONCEPT uses spatial surrogates assigned by state, county, tribal, and SCC code options. The spatial surrogate development tools included in CONCEPT allow the user to develop specialized spatial surrogates where underlying geographic data are available.

Inclusion of Tribal Emission Sources

The NEI format allows input of area source emissions reported by tribal entities. A key issue with inclusion of tribal emissions is whether or not the tribal reported emissions have been extracted from county total emissions reported for overlapping geographic regions. To aid in tracking these emissions, CONCEPT allows a flag on the NEI input record that denotes, when a tribal identifier is encountered, whether the county-based emissions overlap the tribal-based emissions. If the emissions are overlapped between the two reporting agencies, CONCEPT adjusts the county total to exclude tribal emissions, based on the reported SCC codes, and a geographic overlay of the spatial surrogate assigned to the SCC. The CONCEPT system includes calculations to determine the percentage of the spatial feature of the tribal surrogate that is included in the county extent, and uses this as a basis for emissions adjustment.

Point Source Model

As with the area source model, the primary goal of point source modeling is to produce the gridded, hourly emissions estimates for input to a photochemical model, utilizing the temporal, spatial, and emissions information in the ASCII NEIv3 inventory files. The point source temporal processing methodology is similar to the area source processing, making the best use of the temporal detail available in the NEI structures. Other issues of primary importance in the point source model are the inclusion of CEM data, spatial distribution of the point source locations on the modeling grid, and the QA and review of stack parameter data.

Incorporation of CEM Data

The CONCEPT point source model specifically allows the input of day-specific, hourly emissions estimates for CEM source data. Although the NEI format contains the level of detail required to input hourly emissions, a separate set of input file formats and handling routines are available specifically for CEM. These hourly emissions are used in preference to the NEI emissions inputs, when they are available.

Spatial Validity of Point Source Locations

The spatial allocation tools in CONCEPT are used to develop the grid overlays that assign point source locations to specific grid cells. The tools also provide QA checks and reports to validate stack locations (i.e., do the stack coordinates place the stack within the state and county specified by the FIPS state and county code?).

Validity and QA of Stack Parameter Data

Validity of stack parameter data is a primary concern in the development of point source emissions. During the processing of stack parameter data, it is often necessary to supply default data, or recalculate values that are missing or invalid. The database structures used by CONCEPT not only provide standard reporting and review opportunities for QA of stack parameter data, but include reports providing exact details on the origin of stack parameter defaults and calculated values. CONCEPT also maintains the status flags for the stack parameters, which can then be reviewed at any step of the processing.

On-road Motor Vehicle Model

The CONCEPT On-Road Motor Vehicle model (MV) combines vehicle activity data (vehicle miles traveled [VMT] and vehicle trips) with motor vehicle emission factors derived from the EPA MOBILE6 model to generate hourly model-ready emissions estimates. While the mathematics of combining the MOBILE6 emissions factors with the activity data are relatively straightforward, running the MOBILE6 model is generally very time-consuming. The model is not optimized for generating a large matrix of emission factors for different locations, speeds, and meteorological conditions suitable for interpolating or use as a lookup table. Therefore, great care has been exercised in deriving the minimum number of MOBILE6 runs required to adequately represent the conditions of the CONCEPT model scenario.

Vehicle activity data for CONCEPT comes primarily from the Transportation Demand Model Transformation Tool (T3) which has been developed under a separate contract. Data may also be provided directly to CONCEPT in the formats described in the RPO Data Exchange Protocol (RPO DEP) documentation[17]. The data are typically provided for generalized time periods (average day, annual average, or partial day periods) and are temporally allocated to hourly values for the CONCEPT scenario period. In addition, the activity data are spatially allocated to the model grid since the MOBILE6 emission factors are generated by grid cell using the gridded meteorological data.

CONCEPT also reads speed data from the RPO DEP input files, and accepts a variety of instructions for adjusting speeds using volume delay functions. Inputs may specify a Bureau of Public Roads (BPR) style adjustment curve, or a detailed lookup table of adjustments. The curve coefficients and adjustment factors may vary by network link, speed, and volume-capacity ratio, providing a great deal of flexibility in how speeds are calculated. Alternatively, users may provide speed values directly to CONCEPT if they are available (for example, from an external queuing algorithm).

The following twelve steps briefly describe the implementation of the CONCEPT MV model.

Input QA

CONCEPT imports VMT, trips, volumes, network capacity, speeds, network definition, speed adjustments, and meteorological data and performs QA checks. CONCEPT generates both summary and error reports for use by the user.

Eliminate Overlapping Data

Where statewide or local networks overlap with county-level HPMS data, CONCEPT eliminates the HPMS data for the facility types that are provided in the statewide or local network. This is done for whole counties only. The preferred network data are identified where a single county/facility type has both link level activity data and county-level activity data.

Temporal Allocation

CONCEPT mobile source temporal allocation is similar in logical design to the CONCEPT area source temporal allocation. CONCEPT will select closest match activity records for each model hour and apply appropriate profile factors to calculate the hourly activity. Total-volume hourly profiles are used for determining appropriate allocation factors for the hours spanned by each activity record. The profiles are specified by State, roadway type, year, month, and day of week. For partial-hour activity records, CONCEPT applies a time-weighted allocation to an hourly value. Temporal allocation is applied to the VMT, volume, capacity, and trips data.

Speed Adjustment

If the user has indicated that speed adjustments are to be applied, CONCEPT calculates the hourly volume-capacity ratios and applies appropriate adjustments to the free-flow speeds for each link to estimate hourly actual speeds. Some networks may provide these data as output from their TDM or TDM post-processors, in which case the networks are specified as having no speed adjustments in the input data.

Spatial Allocation

MOBILE6 is executed based on gridded meteorological data, so the activity data must be spatially allocated prior to determining the required MOBILE6 runs. The spatial allocation is performed using similar logic to the area and point source spatial allocators. The link-based VMT data are spatially allocated using an overlay of the link network on the model grid. County-based VMT, and TAZ/county based trip data, are allocated to the model grid using spatial surrogates. The speed data are also allocated to the model grid but remain broken out by link id.

Apply VMT Mix Profiles

VMT data are split by the MOBILE6 vehicle classes as input to CONCEPT. The vehicle classes are converted to match the eight MOBILE5 vehicle classes using vehicle mix profiles provided as input to CONCEPT. The vehicle mix profiles vary by state, roadway type, year, month, day of week, and time of day.

Define Required MOBILE6 Runs

MOBILE6 is run for each combination of representative county, minimum and maximum (min/max) temperature combination, calendar year, season (January or July), roadway type, and speed bin. The min/max temperature combinations use a user-defined tolerance level so that similar temperature ranges are considered equal. For example, if the user defines 5 ºF as the tolerance level, a 52 ºF – 74 ºF range would be considered equal to a 54 ºF – 71 ºC range. Also, since the MOBILE6 model is not sensitive to specific dates, each model day is not treated differently as long as the temperature range is handled (the calendar year and season are handled in separate runs for CONCEPT model periods that span years or seasons). For each group of grid cells that fall into the same group by representative county, temperature range, year, and season, the actual roadway types present in those grid cells are examined to determine if both Freeways and Arterials need to be run in MOBILE6. The speeds for which the model is run are also defined with speed bins in the user input. Finally, the MOBILE6 model is run using a single set of 24 hourly values for temperature and relative humidity for each group of grid cells – the values are taken from one selected grid cell within the group.

Execute MOBILE6

A customized version of MOBILE6 developed by Air Improvement Resources (AIR) is used which includes a new option for summarizing the database output. The new option is used to group emissions into the eight MOBILE5 vehicle classes, and to eliminate the variation by model year – this significantly reduces the size of the resulting MOBILE6 output files.

Combine Activity Data and Emission Factors

Generally speaking, for each hour of each episode day, for each link in each grid cell, CONCEPT uses the grid cell ID, representative county, temperature increase bin, road type, and speed to determine the correct emission factor for each vehicle class, pollutant and (non-start) emission mode. Emissions for each vehicle class, emission type, and pollutant are estimated as the product of the emission factor and the VMT on that link associated with the vehicle class. This applies to running exhaust, running losses, crankcase losses, resting losses, particulate emissions from brake and tire wear, and diurnal emissions. For start emissions and hot soak emissions, the number of trips allocated to a grid cell for each hour is combined with a grams per start emission factor associated with that grid cell and hour. Start emissions are only calculated for light duty vehicles.

Speciate the Emissions

CONCEPT uses the same logic as other emissions source models to apply the appropriate speciation profiles by pollutant to generate the speciated emissions. The main difference in the MV model is the inclusion of the emission mode in the definition of which speciation profile to use for each pollutant.

Non-road Mobile Source Model

CONCEPT incorporates the EPA's NONROAD[8] model to produce county level, temperature adjusted emissions estimates for non-road mobile sources. The NONROAD is the US EPA's tool to estimate emissions from off-road equipment of all types except for commercial marine, aircraft, and locomotives. It contains sufficient default population, activity, and emission factor data to estimate emissions by county, equipment, technology and horsepower range. However, the user is encouraged to input more locality-specific data when they are available.

The core NONROAD Model is FORTRAN-based and is incorporated similarly to the MOBILE6 model. Scenario-specific inputs such as fuel specifications, temperatures, and day type as well as the names of external input data files are passed to the core NONROAD Model via CONCEPT processors. The user defines a list of representative counties specifying each of the required fuel characteristics. In addition, every county for which emissions estimates are required for modeling must be mapped to one of these representative counties. All counties mapped to the representative county share the same fuel characteristics as the representative county. The CONCEPT non-road processor generates the NONROAD Model input Options files, one for each representative county and modeling episode month. The NONROAD Model Options File is defined to generate typical weekday emissions for the specified month at minimum temperature 68 ^{o}F, maximum temperature 84 ^{o}F, and average daily temperature of 75 ^{o}F.

After the NONROAD Model completes all runs the output data is then imported into CONCEPT and emissions are summed over horsepower. The detailed outputs are stored in SQL database format. The NONROAD Model supports both weekday and weekend day periods. However, in order to reduce the number of NONROAD Model runs a weekend adjustment factor is applied in the

CONCEPT non-road model to estimate weekend day emissions. In addition, NH3, which is currently not estimated in the NONROAD Model, is estimated as a function of fuel consumption and fuel type.

Like area and point source processors, the non-road processor temporally allocates, speciates and spatially allocates emissions to the episode period, modeling grid and chemical mechanism. The same algorithms of searching for the closest match in determining profiles are implemented in the non-road processor. And finally, adjusting exhaust and diurnal emissions based on gridded hourly temperature data further refines emission estimates. Where the NONROAD Model uses a single minimum, maximum and average day temperature, the CONCEPT non-road processor adjusts the emissions based on actual gridded, hourly estimates specified in the meteorological data.

Biogenic Emissions Model

The new biogenic emissions model mimics the process flow, data inputs, and data outputs that are currently built into BIOME3[18]. This includes formulations for BEIS2 and BEIS3. The foundation data for the new biogenic emissions model have been extracted from EPA's current version of the SMOKE-BEIS3[19,20] (v.09) modeling system with attendant data from BELD3[21,22]. Also, the CONCEPT biogenic emissions modeling system contains the GloBEIS[23] canopy model which is used to attenuate photosynthetically active radiation. Given that the BELD3 is in a specific map projection, the CONCEPT biogenic emissions modeling system has the necessary built-in functions to extract the appropriate BELD3 data and project it to the map projection system specified as an attribute of the CONCEPT emissions modeling grid. The model also performs speciation per the chemical mechanism defined by the user.

Spatial Allocation Development Tools

Emissions estimates that are reported on a county level, such as stationary area sources, need to be spatially allocated to grid cells based on an activity surrogate, such as population, employment, or roadway network. The CONCEPT spatial allocation model provides a means of developing theses spatial surrogates. The spatial components of CONCEPT are fully integrated into the modeling system and the PostgreSQL data base. The GIS components are based on the PostGIS plugin, with added support for geographic objects from GEOS and cartographic map projections from PROJ4, to the PostgreSQL data base. PostGIS offers a full range of GIS functions to perform all aspects of the spatial processing necessary in CONCEPT.

The CONCEPT spatial processing model provides the tools necessary to build an emissions modeling grid. The model provides support for a wide variety of map projection systems including Lambert conformal, geographic, stereographic, and UTM. It also supports map projections using the spherical, NAD27, and NAD83 datums for all map projections and the WGS84 datum in the geographic projection. The CONCEPT spatial model provides the means to load spatial coverages, which are in shapefile format, into the PostgreSQL data base. Indeed, CONCEPT is delivered configured to read in the spatial coverages that EPA has used to construct national area source spatial surrogates. Further, the spatial model provides a means for the user to define spatial surrogates based on the contents of the spatial coverages, which CONCEPT acts upon to build area source spatial surrogates. The CONCEPT spatial model has also been constructed such that it also computes not only tribal-based area source surrogates, but also computes the fraction of each tribal surrogate that resides in a specific county. Finally, the CONCEPT spatial model has been constructed so that the user can extract portions of data from preexisting gridded data sets. That is, CONCEPT has inherent sub-grid processing capabilities.

Speciation Profile Development Tools

A key component of emissions modeling is speciation of the emissions. Emissions inventory data are typically provided using explicit organic species or as a generic family of volatile organic compounds (VOC). Air quality models, however, employ condensed photochemical mechanisms that use only a few model VOC species to represent the thousands of explicit VOCs found in ambient air. Therefore, the emissions processing system requires an algorithm for converting the explicit or generic VOC species to the VOC classes that the photochemical model employs. Each chemical mechanism uses a unique set of VOC classes, thus the emissions processing system must be designed to accommodate speciation for any of the widely used photochemical mechanisms. The most widely used photochemical mechanisms include Carbon Bond –Version IV (CB-IV)[24] and the California Statewide Air Pollution Research Center (SAPRC) [25] at the University of California at Rvierside.

Explicit VOC species are first determined using a SCC-to-explicit VOC profile cross reference. The explicit VOC profile identifies the mass fraction of each VOC in the typical emissions stream. The speciation process uses an explicit VOC-to-VOC class cross-reference file to map the explicit species to a VOC class for the particular photochemical mechanisms being used. The VOC class profile identifies the molar fraction of each explicit VOC in each lumped, or explicit, VOC class. The cross-reference file may be county specific, as in the case of automobile fuels, or nationally uniform, as in the case of residential coal combustion.

The CONCEPT speciation development tool builds the lumped chemical mechanism speciation profiles from raw speciation profiles using the apportionment of the chemical compounds (i.e., EPA SAROAD codes) to mechanism species, organic profiles and SCC's. The speciation development tools can be used for either SAPRC or CB-IV, and will also create appropriate lumped profiles for particulate or other pollutants as long as the proper species cross-reference data are supplied. The model does not hard-code any pollutants and allows users to add new pollutants and species easily. For example, the model has the capability to use toxics inventories if users develop appropriate inputs to the speciation model.

Growth and Control Inventory Development

The application of growth and control factors to the area and stationary sources of the modeling inventory is an essential component of a useful emissions modeling tool. Traditionally, biogenic emissions are not projected into future years, and at this time, they are not included in the growth and control model application. Altering the control assumptions to the Motor Vehicle portions of the inventory requires the re-application of the MOBILE6 model, and is handled independently from the Growth and Controls model. For processing area and stationary sources, the model has the capability to apply one or more growth scenarios, and to overlay one or more control scenarios. The model has the capability to apply growth and control factors in a hierarchical fashion, from a general, state specific factor, to one specific to a particular facility/SCC/pollutant combination. The model also determines if there are existing controls on a source, and if necessary, recalculates the emissions estimate using the new control basis.

The CONCEPT model includes growth and control packages that allow the user to apply growth and control criteria to area and point source emissions, based on a wide variety of selection criteria. Rather than attempting to create growth and control factors to directly alter emissions during the modeling process, the CONCEPT model uses growth and control information to produce new versions of NEI-format data files containing the grown and/or controlled emissions and new control information. This approach allows the user to then run future year cases using alternate temporal, spatial or speciation profiles if desired, and also allows direct QA of the forecast emissions using all the same tools and reports available in CONCEPT for the base year data. Flexibility in application of the growth and

control criteria is a key feature in the CONCEPT model. Currently, area sources have thirty-one separate application levels for applying growth and control factors, and stationary point sources have 103 defined levels to apply growth and control factors. CONEPT can identify and apply controls on either a replacement or incremental basis or as an emission cap.

The CONCEPT growth and control models include additional tools to calculate costs for control strategies and reports those costs for point and area sources. The cost estimates are based on user inputs, such as cost per emission unit and cost per ton values. Basic estimates are automatically included in the forecast processing. In addition, a least-cost option may be selected that reports to the user the cost impacts of various available control options

The initial cost per emission unit (or emission reduction) and capital and O&M multipliers can be obtained through various Federal, State, and industry reports on available control technologies and strategies. In addition to the Air Pollution Control Cost Manuals, Alternative Control Techniques (ACT) and Control Technique Documents (CTG) published by EPA containing various control strategies and associated cost parameters, EPA has funded the development of the ControlNET database which contains a collection of control measures and cost information for reducing the emissions of criteria-type pollutants (e.g., NOx, SO_2, CO, VOC, PM_{10}, $PM_{2.5}$, and NH_3) from point, area, and mobile sources. Utilizing these data, the CONCEPT user can modify, assign, and report the associated emissions reduction and costs from a chosen scenario or set of controls.

As the basic modeling objective for the cost module is to provide quick turnaround fiscal analysis to the CONCEPT user, the module operates independently of the temporal, spatial, or speciation models. This allows the maximum number of runs to define a cost-effective strategy before the more time consuming emissions processing commences.

CONCLUSION

The functionality of a new emissions modeling system, CONCEPT, has been described. CONCEPT is a GNU publicly licensed software system based on the PostgreSQL data base system. Emissions modeling component are currently available for area sources, stationary sources, on-road mobile sources (with MOBILE6 embedded), off-road mobile sources (with EPA's NONROAD embedded), and biogenics. CONCEPT also has extensive capabilities for speciation profile development, spatial surrogate development, and future year growth and control.

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KEYWORDS

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